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(54) ULTRASONIC SCALPEL

(57) The invention pertains to an ultrasonic scalpel in which, in addition to the manual effort of the surgeon, a second active energy (ultrasonic solid-state vibration) is used for cutting soft biological tissue. The instrument vibrates at its resonant frequency as a half-wave resonator. It comprises a rotationally symmetrical shaft specially configured for amplitude intensification, and, joined to that, a working segment which, as a result of its special configuration, cuts in an especially low-force manner in a drawing cut. In contrast to the usual ultrasonic scalpels, the working segment exhibits a convexly, preferably parabolically, curved knife back, and a cutting edge which at its front part runs parallel to the resonator axis and at its rear part is slightly concavely curved. The ultrasonic scalpel can be used in surgery for selected indication areas in which a precise, low-force cutting with little bleeding is sought.

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Ultrasonic Scalpel

Area of Application of the Invention

The invention pertains to an ultrasonic scalpel which vibrates in the ultrasonic range as a solid-state resonator and is used for the separation of soft biological tissue by means of its specially shaped knife-like working segment. The working segment is shaped in such a way that it can advantageously be used for all cuts which are carried out by means of a drawing movement. The ultrasonic scalpel can be used for certain surgical operations in which precise, low-force cutting and preparation of lesions with little bleeding are sought.

Characteristics of the Known Technical Solutions

Along with the conventional scalpel, which is guided by the manual effort of the surgeon during the cut and which has been further developed in a wide variety of forms for specialized operations, surgical cutting instruments have been developed in recent years which, in addition to the manual effort of the surgeon, make use of a second active energy for cutting such as those used in cryosurgery, high-frequency surgery, and ultrasonic surgery, or with the Hamer scalpel in accordance with German Unexamined Patent Application 2611720.

These devices are used for specialized operations in general surgery, but are also used in specialized surgical disciplines as well, such as in neurology, ophthalmic surgery, urology, etc. In

addition to making the cutting easier, the applied active energy usually permits the utilization of additional effects, such as the associated hemostasis.

Ultrasonic scalpels are known for general surgery, as well as for specialized areas such as neurosurgery in accordance with German Unexamined Patent Application 2605986 and ophthalmic surgery in accordance with German Democratic Republic Economic Patent 109 296 and German Unexamined Patent Application 2626 373.

Additional ultrasonic scalpels are described in the Soviet Originator's Certificates 344 851 and 797 677. In most cases, the shape of the working segment (blade) is similar to that of conventional scalpels, the cutting edge of which is curved towards the knife back with a variety of radii, whereby the size of the radius is in accordance with the area of application. In that regard, the knife back runs parallel to the axis of the resonator. Measurements of the vibration amplitude of ultrasonic scalpels have shown that the greatest amplitude occurs at the tip of the instrument, and that it declines along the curved cutting edge to the same extent that the angle between the tangent at the cutting point under consideration and the resonator axis becomes smaller. This means that if the cutting edge is parallel to the resonator axis, a back and forth movement of the cutting points takes place, while no vibration amplitude can be detected perpendicular to the cutting edge. For that reason, these ultrasonic scalpels have the crucial disadvantage that the greatest vibration amplitude, which occurs at the tip of the instrument, cannot be utilized during a drawing cut, so that the reduction of the cutting force of the surgeon's manual effort which is possible does not take full effect.

The rotationally symmetrical part of ultrasonic resonators for carrying out mechanical work usually tapers in accordance with certain mathematical functions from a large beginning cross section to a smaller end cross section to which a working segment is joined. Exponential and hyperboloid resonators, stepped cylindrical resonators, conoidal resonators, and resonators with combined form segments are known. The quality of these resonators depends on the relationship of the amplitude transformation to the resulting maximum work material stress, the manufac-

turing expense, the geometry required for a specific transformation, and the ability to be tuned to the resonant frequency of the sonic transducer.

All resonator geometries have advantages and disadvantages in accordance with the above criteria, and generally represent compromise solutions.

Objective of the Invention

The objective of the invention is, by means of an ultrasonic scalpel to be handled in a drawing cut, to reduce as much as possible the manual effort needed by the surgeon, to increase the quality and the precision of the cut, and thus to improve the operating technique.

Explanation of the Nature of the Invention

The invention performs the task of creating an ultrasonic scalpel in which the vibration energy is concentrated in the cutting area, which cuts precisely and with very little effort in the drawing cut, and which is comfortable for the surgeon to handle, whereby the resonator exhibits little mass and is well matched to the resonant frequency of the sonic transducer.

In accordance with the invention, by means of an ultrasonic scalpel which vibrates as a solid-state body in the ultrasonic range and which is equipped with a specially configured, joined knife-like working segment for the separation of soft biological tissue in human and veterinary medicine, this task is carried out by means of the fact that in essence it contains a rotationally symmetrical shaft comprised of a cylindrical segment and a solid of rotation which continuously tapers concavely in accordance with a radius function, and a joined working segment. The working segment exhibits a convexly, preferably parabolically curved knife back, a rounded

knife tip, and a cutting edge which at its front cutting part runs approximately parallel to the resonator axis and at its rear part is slightly concavely curved.

The distance from the knife tip to the resonator axis is markedly greater than the distance from the resonator axis to the lower edge of the shaft at the transition to the working segment. As a result of that, and as a result of the parabolically curved knife back, the side area of the working segment below the resonator axis towards the cutting edge is greater than the side area above the resonator axis towards the knife back. The curvature of the knife back results from the parabolic apex equation $y^2 = 2px$, where the x-axis is parallel to the resonator axis and the origin of the coordinates lies at the knife tip. The parabolically shaped knife back makes a transition into a radius ahead of the solid of rotation. In accordance with the invention, the knife back can also be convexly curved as desired, whereby the curvature is great with respect to the height of the working segment, and the tangent which is placed on the curve at the height of the resonator axis forms with the latter an angle of less than 50°.

Studies of the ultrasonic cutting process have shown that the reduction in cutting force during the cutting of biological tissue takes place as the result of a number of different effects: The longitudinal vibrations cause high-frequency mechanical impacts on the tissue, and the transverse vibrations which occur lead to a decrease in the friction of the tissue on the side areas of the working segment and to an increase in the separating forces occurring as a result of the wedge shape of the working segment. The rapid back and forth movement of the cutting edge, which is serrated when viewed microscopically, causes a sawing effect and, as a result of the great sound intensity, cavitation takes place in the tissue fluid at the contact surface between the working segment and the tissue. The described ultrasonic scalpel is configured in such a way that all of these effects are put to good use in the drawing cut.

As a result of the fact that the knife tip is located on the straight cutting edge, the greatest longitudinal vibration amplitude, which occurs at the tip, is well-utilized for reducing the cutting force. The wave portions reflected at the knife back in accordance with the invention are

guided into the region of the cutting edge. In conjunction with that, at the locations at which the angle of incidence of the incoming waves is 60° to 70°, it is primarily transverse waves which occur, which cause an additional reduction in the cutting force as a result of increased transverse vibrations in the region of the cutting edge.

Embodiment

In the following, the invention is to be explained by means of an embodiment and with the aid of three drawings.

The following are shown:

Fig. 1 The ultrasonic scalpel in a side view,

Fig. 2 The working segment of the ultrasonic scalpel with enlarged longitudinal vibration amplitude drawn in,

Fig. 3 The design of the parabolically shaped portion of the knife back.

The ultrasonic scalpel in accordance with the invention is made from a titanium alloy. It comprises a cylindrical segment 8 with a diameter of 18 mm, for example, a concave, tapered solid of rotation 7, and a working segment 3, whereby the solid of rotation 7 has a diameter of 5 mm at the transition to the working segment 3. A parabolic parameter $p = 4$ was chosen for the dimensioning of a parabolically curved knife back 1. The origin of the coordinates for the construction of the parabola was placed at a knife tip 2. As a result, the parabolic focal point 11 is at a distance of 2 mm from the knife tip 2.

Adjoining a front cutting part 4, which is parallel to the axis of the solid of rotation 7 that simultaneously represents the resonator axis 6, is a concavely curved rear cutting part 5, on which a longitudinal vibration amplitude 10 occurs as a result of its inclination with respect to the resonator axis 6. The tangent 13, which is located on the knife back 1 at the height of the resonator axis 1, encloses with the resonator axis 6 an angle α of approximately 40°.

The illustrated ultrasonic scalpel, the vibration direction 9 of which is parallel to the resonator axis 6, represents a half-wave resonator the resonant frequency of which is 27 kHz. The cylindrical segment 8 is provided on its end with a connecting screw thread 12 for fastening to an electromechanical line sonic transducer.

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Invention Claim

1. Ultrasonic scalpel which vibrates in the ultrasonic range as a solid-state resonator and which is equipped with a joined knife-like working segment for the separation of soft biological tissue in human and veterinary medicine, characterized by the fact that it in essence contains a shaft which comprises a cylindrical segment (8) and a solid of rotation (7) which continuously tapers concavely in accordance with a radius function, and a joined working segment (3) which exhibits a convexly curved knife back (1), a rounded knife tip (2), and a cutting edge which at its front cutting part (4) runs approximately parallel to the resonator axis (6) and at its rear cutting part (5) is slightly concavely curved, and that the distance from the knife tip (2) to the resonator axis is markedly greater than the distance from the resonator axis (6) to the lower edge of the shaft at the transition to the working segment (3).

2. Ultrasonic scalpel in accordance with Point 1, characterized by the fact that the working segment (3) exhibits a substantially greater side area below the resonator axis (6) than above the resonator axis (6) towards the knife back (1).

3. Ultrasonic scalpel in accordance with Point 1, characterized by the fact that the curvature of the knife back (1) runs in accordance with the known parabolic apex equation $y^2 = 2px$, where the x-axis is parallel to the resonator axis (6) and the origin of the coordinates of the parabola lies at the knife tip (2), and the parabolically shaped knife back (1) makes a transition into a radius ahead of the solid of rotation (7).

4. Ultrasonic scalpel in accordance with Point 1, characterized by the fact that the knife back (1) is convexly curved in such a way that the tangent (13) which is placed on the knife back (1) in the resonator axis (6) forms with the latter an angle $\alpha \leq 50$, and the curvature is great with respect to the height of the working segment (3).

See also __3__ pages of drawings.

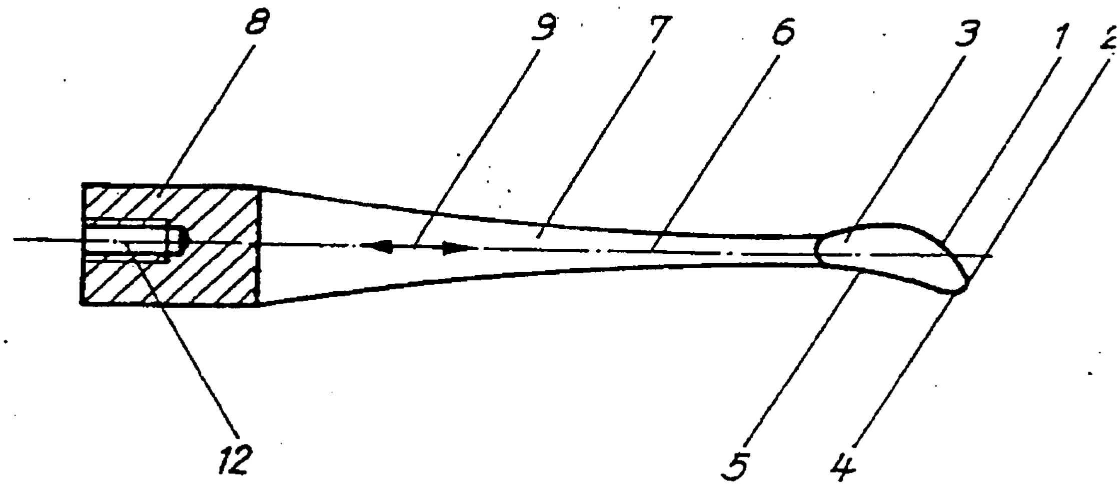

Fig. 1

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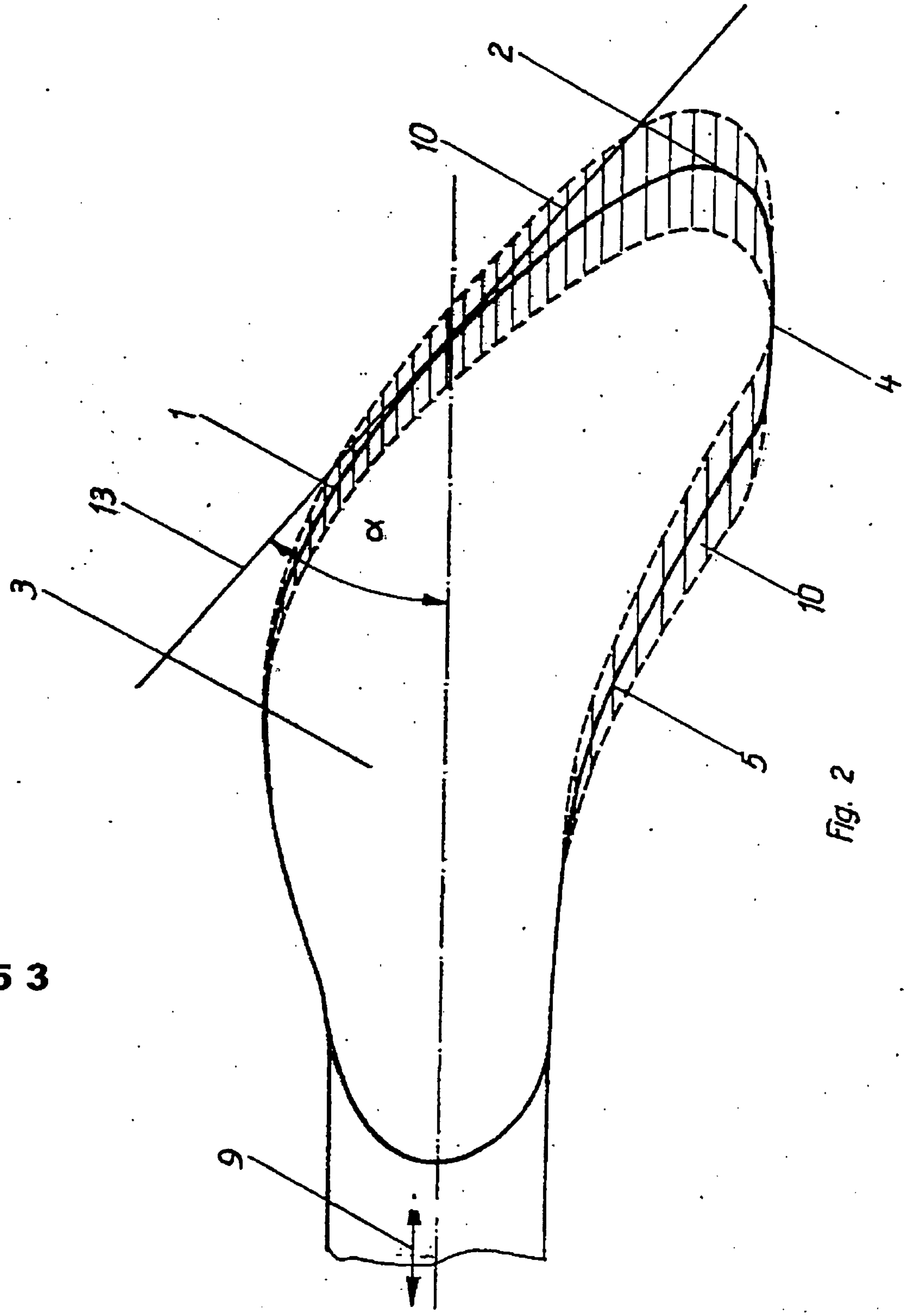

Fig. 2

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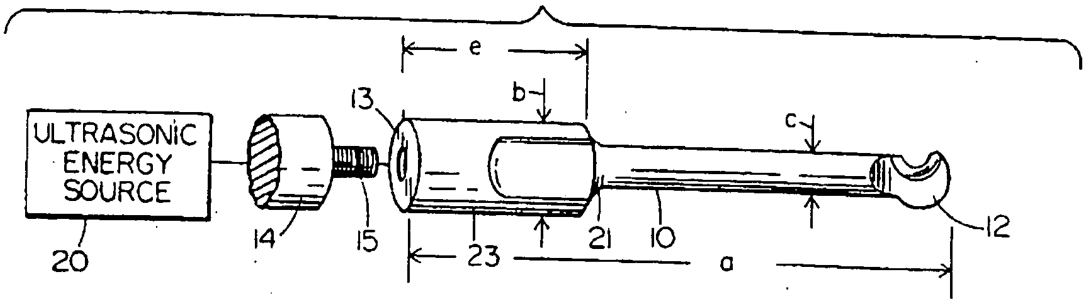
FIG. 1



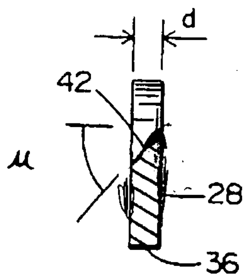


FIG. 3

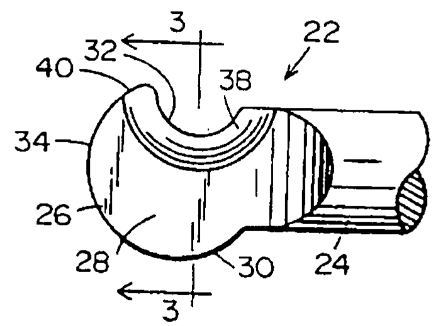


FIG. 2

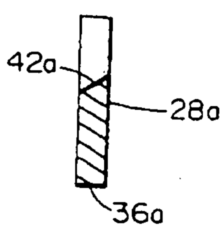


FIG. 5

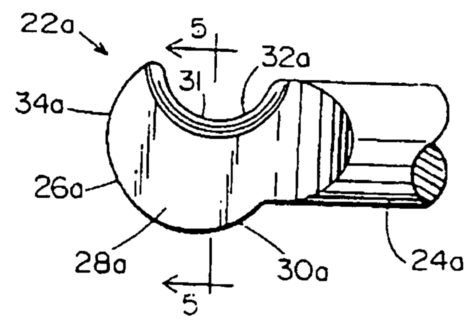


FIG. 4

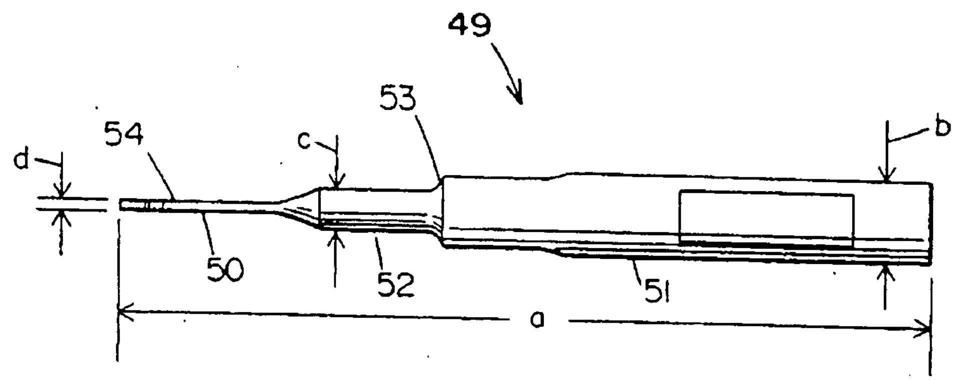


FIG. 6

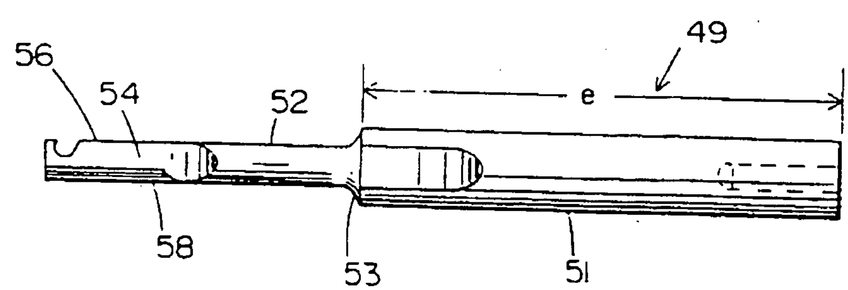


FIG. 7

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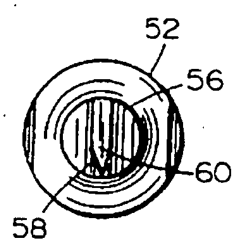

FIG. 10

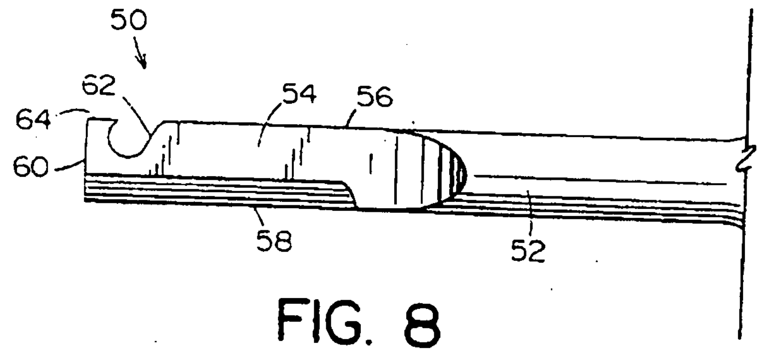

FIG. 8

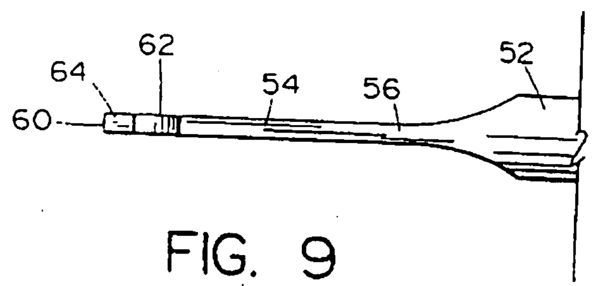

FIG. 9

SUBSTITUTE SHEET